Protocol for Measuring Nitrous oxide Leakage by Weighing cylinders.

Background

Nitrous oxide was an essential Anaesthetic gas due to its rapid onset/offset, analgesic properties and minimal odor. But, it's role in modern medicine is greatly reduced because of modern alternatives, growing awareness of environmental impact and occupational health and safety concerns. It is now only commonly used in maternity and children's hospitals.

Nitrous oxide has a global warming potential of 273. Which mean 1kg of Nitrous causes the same global warming effect over 100 years as 273 kg of CO_2. Current purchasing levels mean it contributes 80-90% of anaesthetic greenhouse emissions.

Australian the occupational limits are set at 50ppm. The occupational health concerns with nitrous oxide exposure include miscarriage, mental impairment, neurotoxicity, DNA damage, and induction of vitamin B12 deficiency. Additionally, It supports combustion equally as effectively as oxygen.

For most of the 20th century, hospitals were designed with reticulated nitrous oxide from a nitrous manifold with multiple G cylinders or F8 packs. This infrastructure is now ageing, and most hospitals have significant problems with unwanted leakage of nitrous oxide from the pipework system.

There are multiple sources of leakage from a reticulated pipeline system in an ageing hospitals.

a) Wall outlets: there may be two or more in each location that the original hospital architect expected to be used for patient care. Often these rooms have been converted to other uses, without removal of the pipework supply.
b) Operating room pendants are attached to the pipeline system and may leak from the connection to the pipework or outlet (often hidden behind a ceiling or wall).
c) Leaks may occur from isolating valves in the pipeline system.
d) Therapeutic equipment attached to pipeline gases may develop leaks with time.
e) Rarely, the pipeline itself may be damaged and develop a leak. We have seen this at SCGH, with a massive, but undetected leak that persisted for several months.

The Australian standard (AS 2896) have proven inadequate in detecting many of these leaks. The standards direct the areas which have a high chance of leaking (Wall outlets and manifold) are subjected to the "soapy water test". This has limited accuracy to identify leaks and cannot be used in difficult location like the theatre pendants. Area of low chance of leaking are never tested.

Historically there have been no attempts at measuring leaks with any degree of accuracy. Some new ideas have been developed to identify a leaks in the system:

1. Pressure testing the system.
    a. Knowing the volume of the system and the rate of pressure drop allows calculation of leak.

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Rate of Leak = vol/time = volume of gas in piping X (percentage pressure drop / time)

b. System can be checked as a total system – but this has some problems.
    i. Even a large leak, eg 1l/min would only be slowly recognized if the volume of the system is 500L. In this case only a 0.2% fall in pressure per minute.
    ii. If a greater than 20% drop in Nitrous oxide pressure did occur – then all the hospitals Nitrous oxide pressure alarms would alarm. Although unlikely to occur, significant preparation would be required to safely do this test.
c. System can be checked in sections beyond any isolation valve.
    i. Isolation valves are normally at the start of any major limb of the pipeline system and at each theatre or small group of theatres.
    ii. In theatre is possible to use the anaesthetic machine as the "pressure gauge" or connect a more sensitive gauge.
    iii. Advantage of small volume gas in the system, which makes it more sensitive / quicker to detect a leak
    iv. Advantage that only local alarms may go off.

2. Flow monitoring. Flow of gas from the manifold in a period of no use would equal the leak. It is possible to add flow meters near the manifold but this has not been tried yet. It is being investigated at several sites.
3. Monitoring the Weight of a Nitrous cylinder – This briefing note proposes a simple method using an electronic balance to identify leaks in a nitrous oxide pipeline system with substantial improvement in accuracy.

Theory of Weighing a Nitrous oxide cylinder**.**

Zero usage of Nitrous oxide for a short period of time is relatively easy to organize in a hospital.

a) Maternity units can use Entonox cylinder.
b) Anaesthetists have other choices of agents.
c) Other areas in the hospital eg ED, Burns dental units can use nitrous oxide or Entonox.

During a period of "no usage" any change in cylinder weight could be assumed to be from leak.
If stopping nitrous use in all departmental is difficult, the random usage of nitrous predicts that there will be times of no nitrous usage. A moderate leak will be much larger than some incidental usage, and the graphed data should make use vs leak apparent.

Measuring weight change of a cylinder is possible – As demonstrated at the Alfred Hospital, using time lapse photograph to record the weight displayed on the scales over an 18 day period (1).

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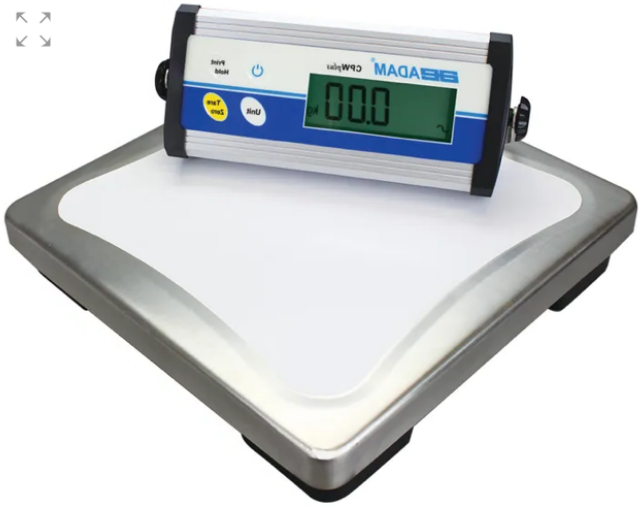
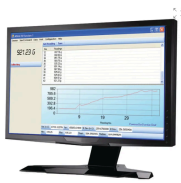
Equipment required for an 3 hour test for a Hospital with flexible hoses connecting cylinders to the manifold



RS-232 to USB adapter-3074010507

RS-232 cable-3074010266



AdamDU Data Collection Program-600002028

1) Adam CPW plus 6M Scales (upto6kg, 2g increments) (Scales only 5cm high)
2) RS-232 data cable and RS 232 to USB converter cable.
3) PC with Adam DU Data collection program
4) Full C cylinder (1.75kg of Nitrous)
5) Power cable and Double adapter to power – scales and computer.

Testing Procedure

** **requires close consultation approval and co-ordination with facilities management** **

1) Co-ordinate no/minimal usage of Nitrous in the hospital.
    a. Organise Entonox for the maternity ward
    b. Request no use of Nitrous in Theatres.
    c. Ensure no other units using Nitrous. (eg ED)

    This is probably easiest to organize for an overnight / weekend.

a) At the Manifold
    a. Switch the “change over mechanism “so the system is now running off the full (unused) G cylinders.
    b. On the “reserve” side of the manifold (partially emptied F8 / G cylinder)
        i. Turn off the F8 or all the G cylinders
        ii. Slowly Disconnect the high pressure flexible hose from the F8 or one of the G cylinders at the pin connection (Do slowly as some high pressure gas in hose will be released)
        iii. Connect the high pressure flexible hose to the full C Cylinder
        iv. Place the scales under the C Cylinder
        v. Slowly Open the C cylinder.
    c. Switch the “Change over Mechanism” so the one C cylinder on the scale has become the “in use” cylinder.
    d. Do not alter the cylinders on the other side of the manifold – Leave on.

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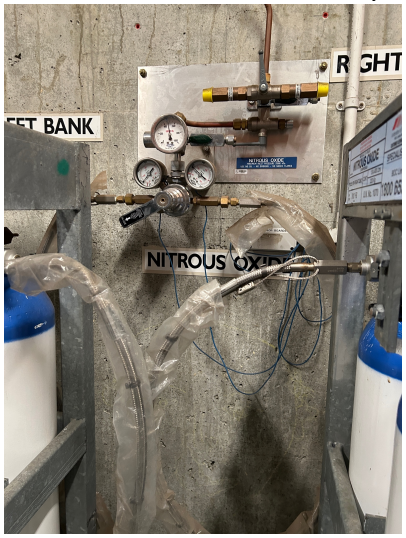
If the single C cylinder empties – then “Auto change over” will occur to the other side which is a full F8 /G Cylinders and a constant supply of Nitrous will be maintained.

b) Connect the Scales to the PC & start the Adam DU software.
    a. Select Constant data collection – every 1 min.
c) Sensitivity: 3 Hour test – 6g change in 3 hour = 22kg/yr (this would be a very small leak)
    a. The C cylinder would empty if leak > 5,000 kg/year. (No hospital has this leak)
d) End of Test – reverse process to reconnect F8 / G cylinders



References

1. Gaff SJ, Chen V. Investigating nitrous oxide wastage from hospital manifold-pipeline networks: the Alfred protocol. May 2023 [unpublished personal communication].

Cylinder	Tare Weight	Gross Weight	Kg of Nitrous	L of Nitrous	CO2e kg
F8	530	763	233	124,400	61745
C	3.41	5.16	1.75	935	463.75

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